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ABSTRACT

Differences in learning processes were studied in more versus less intellectually able undergraduate students. Thirty subjects were selected to represent a wide range of general and mathematical reasoning abilities, based on the following test scores: Necessary Arithmetic Operations and Vocabulary Test V2 from the Educational Testing Service ETS Kit of cognitive factors tests, the Institute for Personality and Ability Testing (IPAT) Test of "g", and the American College Test mathematics scores. The subjects studied introductory statistics and were then tested, over a one-week period, on cued recall, free recall, multiple choice, concept organization, and similarity rating tasks. Results indicated that ability differences were relatively small for simple tasks, but increased dramatically as task complexity increased. The concept organization and similarity rating task results supported the hypothesis that high ability subjects manipulate incoming data more effectively, producing more richly elaborated conceptual networks, and thus facilitating performance. (Author/GDC)

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Learning and intelligence: Ability differences in the organization and recall of elementary statistical concepts

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Running head: DIFFERENCES IN ORGANIZATION AND RECALL

Abstract

Although learning and intelligence are central constructs in education, many studies have found little if any relationship between them. This study investigated process differences between more and less able students, using learning measures sensitive to a wide range of learning outcomes.

Thirty subjects studied an introductory statistics booklet, and were tested over a one-week period. Learning measures included traditional (cued recall, free recall and multiple choice) and non-traditional (concept organization and similarity rating) tasks.

Ability differences were relatively small for simple items or simple tasks, but increased dramatically as either item or task complexity increased. The concept organization and similarity rating results support the hypothesis that high ability subjects manipulate incoming data more effectively, producing more richly elaborated conceptual networks, thus facilitating performance.

Although learning and intelligence are central constructs in education, the relationship between them is at best only partly understood. Early theorists presumed that ability to learn and intelligence were synonymous, partly because of the consistently high correlations typically observed between measures of intelligence and achievement (see, for example, Spearman, 1904).

However that assumption was challenged by Woodrow (1946) who, in a classic series of experiments, found essentially no relationship between measures of learning and intelligence. He also found no evidence for a general learning factor in the correlations of the learning measures derived from the learning tasks he used, and concluded that learning ability and intelligence were virtually unrelated. Woodrow and many other researchers in this tradition used learning tasks designed to minimize the potentially confounding effects of uncontrolled variables (such as prior experience) on measures of learning. Thus these learning tasks often bore little resemblance to typical classroom learning episodes. For example, tasks frequently involved the use of nonsense syllables and paired associates. The structure of these tasks virtually precluded meaningful learning such as elaboration by comparison/contrast, or construction of set/subset hierarchies, in favor of rote memorization. The guiding philosophy stated that learning was reducible to discrete mental bonds established and strengthened through practice.

Cognitive theories of learning, however, stress the interrelatedness of all knowledge. Experiments such as those of Bartlett (1938) and Bransford and Johnson (1972) have strengthened the hypothesis that what is learned is in large part a function of what is already known. Snow and Lohman (1984) have theorized that this relationship between old and new knowledge is fundamental to a process theory of aptitude for learning from instruction. They have further underscored the need for a theory of aptitude that recognizes the active nature of learning and focuses on flexible adaptation in learning and transfer.

In this study we attempted to investigate process differences between more and less able students. We tried to employ tasks that were "ecologically valid" (Bronfenbrenner, 1976), and to use measures of learning that would be sensitive to a wide range of learning outcomes; from simple recognition and recall to complex restructuring and integration. The goal of this study, then, was to investigate learning processes and learning outcomes that differentiate able from less able students.

Method

Subjects.

Initially 107 undergraduate students from the educational psychology classes at the University of Iowa participated in a screening session for class credit. Thirty students (12 male and 18 female) representing a wide range of general and mathematical reasoning abilities were selected from this subject pool for the

experimental phase.

Screening.

All subjects took three tests; Necessary Arithmetic Operations and Vocabulary test V2 from the ETS kit of cognitive factor tests (Ekstrom, French, & Harmon, 1976), and the IPAT test of "g" (Cattell & Cattell, 1963). Subjects also completed a short biographical questionnaire. The bivariate distribution of ACT math scores and the Necessary Arithmetic Operations scores was used to select a representative sample of 30 subjects for the experimental phase.

Main Experiment.

Each of the 30 subjects participated in two separate sessions. The first session lasted two hours, and consisted of a study phase and a testing phase. For the study phase, subjects were given a specially prepared booklet of basic statistical concepts. This booklet was a synthesis of chapter 12 from Clifford's (1981) educational psychology text, with supplementary information from the Blommers and Forsyth (1977) introductory statistics text. All material was relevant to the subjects' course of study in their educational psychology classes. Subjects were told that information in the booklets was relevant both to the experiment and to their later classroom studies. They were then instructed to study the material in their usual manner (underlining, note-taking, outlining, etc.) until they felt they understood the material. (A one-hour time limit had been predetermined, but was only actually imposed on one

subject.) Subjects were further told they would be given a series of tests following the study period. Study time averaged 55 min.

The testing phase began with a cued recall test of concept definitions, followed by a faceted (rote memorization versus synthesis items) multiple choice test. Following this test, the subjects were allowed a 5 min break. Upon returning to the task, subjects were given a free recall task in which they were told to teach back to the experimenter, in as much detail as possible, all the information they recalled from the study materials. Subjects' protocols were recorded on audio tape and later transcribed. Finally, each subject was given a randomly ordered list of key concepts from the study materials and told to reorder them in a more meaningful manner. This concluded Session 1.

Session 2 lasted one hour, and began with a review phase during which subjects reread the booklet one time. Then, subjects were given another cued recall test and another faceted multiple choice test. Next, each subject rated all possible unique pairings of 16 key terms from the study material, according to their perceived degree of similarity. After that task, each subject completed a study skills questionnaire adapted from Schmeck (1983). This concluded Session 2.

Each subject was tested individually for each session. Sessions were approximately one week apart for each subject, and were all completed at least one week before the material was taught in class.

Results

Ability level had been previously defined by each subject's relative position on the bivariate distribution of ACT math and Necessary Arithmetic Operations scores. As expected, this measure was positively related to performance across all tasks, though these correlations were not all significant. Highest correlations were observed for the teachback task (r = .46, p < .01); the cued recall task (r = .46, p < .01); and the multiple choice test (r = .42, p < .05). When the multiple choice test was divided into rote memorization questions and higher order, synthesis questions, ability level correlated significantly with synthesis scores (r = .46, p < .01), but only moderately with rote memorization performance (r = .30, p = .15).

Item analyses of the free recall and cued recall scores were conducted for the 10 most able and 10 least able subjects. High ability subjects outperformed lower ability subjects in their ability to define virtually all concepts, regardless of whether the concepts were simple (e.g. mean, median, mode) or complex (e.g. standard deviation, z score).

Teachback protocols were analyzed for accuracy and completeness of definition by assigning each defined term a value from 0 to 2 depending upon its rated completeness, clarity, and conformance with the study booklet. Two graduate students performed the rating, and inter-rater reliability was .89. High ability subjects significantly outperformed lower ability subjects on this measure (t=1.87, p < .05). Other measures of

comprehension and retrieval of complex, non-definitional connections and relationships among concepts correlated moderately with ability. No significant difference was noted in the number of concepts mentioned or the number of definitions attempted. There was also no significant difference in the number of examples used to illustrate concepts, although high ability subjects tended to use more complete and appropriate examples, and also to use examples to illustrate more complex concepts.

Concept reorganization task protocols were also rated by two graduate students for the degree of organization (inter-rater reliability = .93). Higher levels of organization displayed hierarchical or network structures and clusters, whereas lower levels showed only simple reordering of concepts. Organizational level correlated significantly with recall of higher order concepts in the teachback task (r = .41, p < .05), and with performance on the cued recall test (r = .36, p < .05). organizational level also correlated moderately with ability level, ACT math scores, and the use of examples on the teachback task.

Marks, comments, and notes made by subjects on the study materials were also analyzed. There was no clear tendency for any group to favor any particular form of elaboration. Notetaking, highlighting, and underlining were all evenly distributed across groups. There was a surprisingly strong tendency for lower ability subjects to paraphrase their notes,

whereas higher ability subjects tended to copy information verbatim. Interestingly, most paraphrasing was either incomplete, irrelevant, or incorrect. There was a slight tendency for lower ability subjects to emphasize technical information such as formulas, whereas higher ability subjects tended to emphasize relationships among concepts.

Similarity ratings were analyzed using ALSCAL, INDSCAL, and cluster analysis procedures. The cluster analysis yielded no significant ability differences in average similarity rating, number of distinct clusters formed, or in average cluster size. However, lower ability subjects did tend to produce fewer, larger clusters (r= -.35, p = .07). Additionally, the number of distinct clusters formed correlated with recall of complex relationships in the teachback task (r = .45, p < .05).

The ALSCAL and INDSCAL procedures indicated two general dimensions that subjects used to rate concept similarities. Dimension 1, defined as a score distribution dimension (e.g. heterogeneous/homogeneous), accounted for 32% of the variance in similarity rating variance for the high ability subjects, and 28% of the variance for lower ability subjects. Dimension 2, loosely defined as a testing and measurement dimension, accounted for 22% of the variance for high ability subjects and 25% of the variance for lower ability subjects. High ability subjects divided dimension 2 into two distinct clusters; a hypothesis testing cluster and a score descriptor cluster. Lower ability subjects did not distinguish these clusters, but rather viewed dimension 2

as a single, undifferentiated cluster. Lower ability subjects may have grouped pairs of terms together on the basis of acoustic similarity (e.g. statistics and statistical hypotheses). Distances between acoustically similar terms were generally less than distances between any other pairs of terms in this dimension. The two dimensions accounted for 55% of the variance in subjects' ratings.

Discussion

The purpose of this study was to investigate the processes that able students use while learning that contribute to their superior performance in typical learning situations. Although this study was thus primarily exploratory, several noteworthy points can be raised.

First, high ability subjects tended to outperform lower ability subjects in specific ways. Differences in performance were relatively small for less complex terms and also for less complex tasks. As items or tasks increased in complexity, however, the performance of high ability subjects increased dramatically. For example, superior performance on the cued recall task seemed to be due primarily to superior definition of complex terms, and superior performance on the multiple choice test was primarily due to expertise on the higher order synthesis questions. This may be because more able subjects tended to manipulate incoming data more effectively, establishing more, stronger connections among concepts, thereby improving both quantity and quality of recall. Thus their performance on more

complex concepts and tasks requiring initial cue generation (e.g. free recall) was facilitated by their more richly elaborated cognitive networks. Whatever the nature of the mechanisms responsible, this study seems to indicate that superior performance on higher order processing tasks rests on a solid declarative information base at more elementary levels.

The concept reorganization and similarity rating data indicate a tendency for able subjects to organize data along more conceptually appropriate lines. Though the data are merely suggestive, and the range of ability is not as broad, some parallels do exist with the expert-novice literature (see, for example, Chase & Simon, 1973; Chi, Feltovich, & Glaser, 1981). For instance, the similarity ratings indicated that higher ability subjects tended to associate items based on definite conceptual relationships, whereas lower ability subjects appeared to use conceptual relationships less, and to focus equally on superficial characteristics such as acoustic similarity. This focus on surface characteristics also detracted from the richness of the conceptual relationships, as more terms were connected by surface relationships only, or were left semantically unrelated. Similarly, the concept reorganization data suggest that high ability subjects tended to organize concepts around logical themes, such as set/subset and comparison/contrast distinctions. On the other hand, less able subjects used fewer devices to segment their knowledge structure into conceptually related categories. The crucial difference between able and less able

students concerned the nature and number of relationships established between facts rather than in the fact that facts were stored.

Finally, as befits an exploratory study, we note some suggestions for future research. First, although the ecological validity of this type of experiment is significantly greater than that of the usual laboratory experiment, it is still a relatively meager sampling of actual classroom instructional situations. Future studies will examine these sorts of process variables over a longer instructional period.

Second, several tasks need to be redesigned to estimate better the process differences between high and low ability students. Differences in the type and amount of elaboration, and in assembly, control, and performance processes can be revealed best by measures that specifically seek this information, rather than traditional global test scores. For example, the similarity rating task measures only one of the elaborative processes students may use to code, store, and retrieve information. It may be more useful to allow students to select their own methods for connecting pairs of terms, thus perhaps providing insight into students' idiosyncratic concept-relating techniques. The nature of the association formed between concepts may be more important than the simple fact that some relationship is noted.

In spite of these limitations, however, we believe that the range of complex learning outcomes assessed in this study provides the sort of framework that is needed to understand the

complex relationships between measures of scholastic aptitude and learning. The results of this study are currently being used in planning and constructing a more in-depth investigation to be conducted later this year.

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